J. Maxillofac. Oral Surg. (Jan–Mar 2019) 18(1):124–130
https://doi.org/10.1007/s12663-018-1107-2

ORIGINAL ARTICLE

Emergency Treatment of Blast, Shell Fragment and Bullet Injuries to the Central Midface Complex

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Received: 22 January 2018 / Accepted: 26 March 2018 / Published online: 29 March 2018

Abstract

Purpose Current ballistics and high-energy explosion possess unnoticed, new and significant biophysics and pathophysiology wounding effects that are unique in comparison with civilian trauma. The primary blast wave effects of compressed air due to explosion lead to tattered and crushed eggshell injuries to the upper central midface (UCM). High-energy shell fragments of various shapes and sizes cause extensive destruction and are different from assault rifle's bullets that cause high energy transfer to the *tissue by* creating a temporary cavitation.

Methods Twenty-one patients with unquantifiable war injuries were selected. The emergency managment of lifesaving facial war injuries starts with life threatening hemorrahge or air compramise. This article describes immediate management of medial canthal tendon (MCT), intercanthal region and severe nasal war injuries.

Results The utilized procedure obtained good results compared to the results of cases treated only by applying a classic approach of civilian fractures.

Conclusion Treatments of UCM injuries are the most difficult since UCM includes the esthetic, physiologic, and anatomical regions of the face. The proposed technique provides immediate excellent stability for soft tissues, bone, and cartilage and is well tolerated in the long term by both the tissue and the patient. Most of the times, victims are treated with limited resources, deficient subspecialty, massive injuries, during mass casualties, and a single surgeon must have to handle all these within a short period of time. UCM injuries are really concerning since this region is the core of facial esthetic and function.

Keywords Blast · Shrapnel · Bullet · Upper central midface · Nose · Orbits · Ethmoid

Introduction

Despite the technological advances in the twenty-first century, armed conflict regrettably dominates life in more than 80 countries around the world. It is estimated that 90% of casualties due to the current conflicts and terrorist explosions are civilians, the majority of whom are women and children, compared to the last century when 90% of those who lost their lives were military personnel [1].

Regrettably, worldwide, most of the civilian surgeons lack the experience of managing massive injuries and mass casualties and have the least interest in armed conflict news.

Anatomically, UCM consists of the frontonasal maxillary process/medial orbital rim, nasal bone, and upper nasal septum/ethmoidal perpendicular plate. The intermediate central midface consists of the medial part of the inferior orbital rim, anterior antral wall, and the para piriform buttress of the nasal bones that are interposed above the nasal aperture between the frontonasal maxillary processes that form the nasal sidewalls and medial orbital rims conjointly [2].

Naso-orbito-ethmoid (NOE) injuries have been the most difficult facial fractures to treat. Even with craniofacial surgical techniques, computed tomography (CT) imaging, miniaturized plate and screw fixation devices, and the collective experience of many notable surgeons, a flawless

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treatment outcome is still elusive [3]. Civilian trauma fractures to this region lead to a widened telecanthus and a displaced medial canthal tendon (MCT) that is distant from its anatomical position. They may also lead to complex cribriform plate injuries, cerebrospinal fluid (CSF) leakage, and cerebral injuries; thus, it is integral to look for signs of a CSF leak [4–8].

Wheras firearm injuries vary in their clinical presenation and depend on the anatomical structures involved. Obviously seen in the upper midface injury as that of the orbital, nasal and cranial bone fragments and cartilage matted in soft tissue strands and no anatomical landmarks will be evident. Immediate reconstruction and scaffolding for reasonable time will prevent additional complications, since this region is the core of facial esthetic and function.

Biophysics and Pathophysiology

Technically, the blast, shell fragment and bullet pathophysiological of injury is directly related to the amount of energy transferred to the target's tissue inflicting different tissues mutilations. Compared with other parts of the face, the midface appears as the more frequently damaged area.

Blast injuries due to conflicts or terrorist IED *explosions that* produce compressed air primary *blast wave effects generate* a significant transfer of *kinetic energy*, inflicting a unique pattern and masked killing effects, creating serious multiple injuries, specifically to the air-containing structures such as sinuses and lungs.

The air molecules are compressed to such a high density that the pressure wave itself acts more like a solid object striking a tissue surface. Slotnick [9] stated that this positive blast wave's thin layer of compressed air moves in all directions, exerting pressures of up to 700 tons per square inch on the atmosphere surrounding the point of detonation at velocities of *up* to 13,000 miles per hour or 29,900 fps.

The clinical findings have revealed that the implosion and miniature re-explosion of compressed air sinuses led to shredded, tattered, and crushed eggshell skeletal injury to the NOE, maxillary sinuses, and nasal structure [10] (Fig. 1, 2).

The ballistics injury's pathophysiology is directly related to the amount of energy transferred to the target's tissue. The energy imparted is determined by the missile's velocity and mass, as expressed by the equation: $E = mv^2/2$.

Shell fragments of warhead/IED explosions result in a spray of different sizes of high-energy fragments, and the wounds they inflict are distinctive. Shuker (2016) [11] stated that shrapnel inflicts extensive complex injuries and soft and hard tissue loss that there are no more morphologic anatomical features of the maxillary sinuses, nose, and NOE.

Fig. 1 Severe midface blast injury showing shredded and crushed nasal structures

Fig. 2 Anteroposterior radiograph of the skull showing skeletal crushed eggshell injury and no anatomical features in the upper central midface, due to primary blast wave effects by implosion phase

Most of the combat injuries are penetrative and caused by fragments from explosive munitions (70–80%), rather than by bullets fired by military small arms [12]. The etiology of these injuries acounts for a combination of the structural character, kinetic energy transfer, and its interaction with tissue which depends on its mass, size, density, the angle and partten of its flight, as well as the tissue characteristics.

A bullet's KE transfer and the biophysics of its wounding effects are unlike those of shell fragment injuries, even though they both have the same mass and equal impact velocity. Increased tissue damage may result from the tumbling of non-deforming rifle bullets which increases the energy transfer to the wound, thus increasing its size, also producing pulsating cavitation effects [13].

The bullet pressure generated in the tissues by a temporary cavitation effect should be questioned in the region, because it is an anatomical architecture that consists of different cavity sizes and multiple air sinuses as it is in UCM. The absence of bulky muscles generally tends to mitigate cavitation effects produced by high-velocity missiles in this region [14].

Patients

These patients were treated with limited medical resources in a risky environment, with multiple injuries, massive wounds, mass casualties and scarce subspecialists.

Twenty-one NOE patients with blast and ballistics midface complex injuries were selected from an unquantifiable large number.

a. Six patients suffered from explosive blast injuries. Four of them suffered from a severe wound, with shredded and crushed tissue in the UCM region. One of them sustained a severe crushed eggshell injury with minor skin lacerations. One patient was followed up 3 weeks later for delayed secondary treatment of midface blast injuries that potentially leads to significant functional and cosmetic complications, in addition to making late reconstruction difficult for the surgeons involved.
b. Nine patients suffered wounds from shell fragments with high and low energy release. Two patients sustained penetrating fragments and in seven patients, perforation injuries inflicted a loss of delicate anatomical tissue, leaving gaps of lost tissue upon exiting. Large fragments caused flattening of the nasal bridge, telecanthus, enophthalmos, ptosis, CSF leakage due to rhinorrhea, intranasal laceration, and septic and skeletal avulsion.
c. Three patients suffered gunshots to the submental region route through the floor of the mouth, tongue and fractured mandible, passing through the hard palate, nasal cavity and NOE region leading to complex injuries through it is route and exiting through the frontal bone, as shown in Figs. 3, 4.

Fig. 3 Entrance of rifle bullet impact to the submental region and exited frontal region. Inflicted fracture to mandibular body, avulsed tongue, routed through the palate, and shattered intranasal cavity, causing injuries to the NOE and exited through the forehead

Fig. 4 Excellent results by single immediate surgery approach, patient image after 1 year

Methods

Emergency management of combat and terrorist IED injuries should begin with prioritizing an assessment of any life-threatening hemorrhage or air compromise. These injuries are highly contaminated and consist of severely lacerated broken tissue; thus, waiting for a hematoma and edema to subside in an "especially hot climate" is not a beneficial choice. In these injuries, secondary tissue damage within the zone of extravasation results from early ischemia and vascular compromise, induced by high-energy ballistic penetration. In view of this, the removal of dead or devitalized tissue remains a key component of wound management, providing the usual rationale for surgical debridement. A delay in that action for more than 24 h appears to complicate the further treatment, as it has been associated with increased tissue necrosis.

Surgical Management

Emergency management should start with a general checkup from head to toe for 4–5 min, during which life-threatening conditions such as hidden missile entrance to chest or abdomen may surface. Medial canthal ligament, intercanthal space, and nasal and maxillary sinus walls should be assessed by gentle manipulation before exploring the wound.

Medial Canthal Ligament

The surgical approach begins with the direct management of the medial canthal ligament and reconstruction of fragmented bone and soft tissue of NOE. In most cases, the tendon requires a minimally invasive approach to the medial canthal region for direct transnasal fixation via wiring, and repositioning of the MCT. A double-armed suture or a suture with a free needle is used to place the stitch on either side of the lachrymal tendon. This ensures that the MCT has been fully grasped, fine wire such as a 26- to 30-gauge steel wire (used for a bilateral canthopexy) is used, the same procedure is performed on the counterlateral side and these two sutures are tied to one another to bring the bilateral MCT to the correct position [15].

For cases of delayed secondary treatment for NOE ballistic/blast injuries, the surgical approach begins by breaking through an existing scar or wound in the region. Regarding orbital floor blowout and sink eye, surgical repair is not as simple as the manipulation and mobilization of a new wound. An iliac crest bone graft has been successfully used to locate the eyeball to its correct position, as shown in Figs. 5, 6.

Intercanthal Region

Extra-nasally, in the intercanthal region, the small fragmented bones and tissues can be shaped with manipulation, for example by pressing it with two fingers on the outside and the elevator from the inside to obtain a superior nasal region shape. We should be careful not to affect the cribriform region by pushing the elevator above toward the brain. While the bilateral medial orbital walls are tight, stainless steel wire or nylon silk needs to be passed through

Fig. 5 Delayed primary blast wave injury shows a unilateral crushed NOE and nasal region injuries, as well as a blown out orbital floor, sunken left eye and facial flush burn

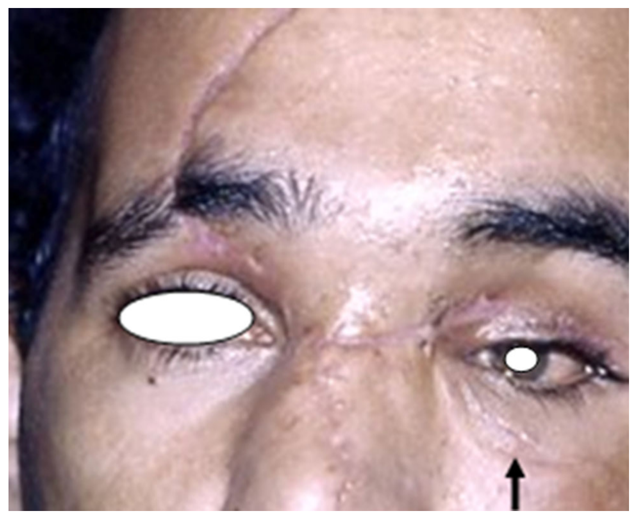

Fig. 6 Showing reconstruction results, starting with direct left-side MCT fixed in position, bone graft of orbital floor. Patient 5 months later with acceptable result

the hall of two buttons and transnasal tissue, from one side to the other, to maintain the stability of the appropriate morphological form.

Intranasal Scaffolding Stenting

Shuker 1988 [16] proposed a new technique utilizing adapted portex tracheostomy tube to fit the severely injured internal nasal cavity to preserve the internal anatomical shape and physiological function. This provides a stable airway of a parabolic shape in the middle meatus region. The convex curvature of the tube's arch is heated in a flame, and its upper part is squeezed with straight artery forceps and immersed in cold water to harden. Hard and soft tissues are built on the tubes with only external nasal skin tissue sutures. When the medial *maxillary sinus wall* is fragmenated, iodoform paste on a pack of ribon gauze should be used inside the sinus cavity to preserve thae sinus orginal shape and prevent blood clot accumilation. Then, the tubes are fixed to each other and to the nasal ala. Buttons can be removed after 2 weeks while intranasal tubes remained in that position for a month or more, as shown in Figs. 7, 8, 9, 10 and 11.

Results

The obtained healing results were acceptable, functionally and esthetically, using the immediate approach. Most patients had a shorter hospital stay and faster rehabilitation and required less follow-ups. Post-traumatic CSF leaks were rarely observed or experienced and had generally been resolved over time.

The immediate emergency surgical approach protects the lacerated tissues, stops the bleeding, reduces the subsequent disfigurement, and preserves the esthetic architecture of the UCM region. This technique was applied by the author routinely for an unquantifiable number, during the 1980–1988 Iraq–Iran war, the 1990 Gulf War, and some internal conflicts. High power ammunitions were widely used in these wars; therefore, the number of daily casualties was very high for which surgeons should be prepared. This method obtained very good results compared to the results of cases treated only by utilizing a standard approach of civilian fractures (Fig. 12).

Fig. 7 Showing 5–6-cm-long penetrating shell fragment through left lateral nasal length and settled in nasal cavity. Imposed sever nasal tissues distraction and nasoethmoid orbital region

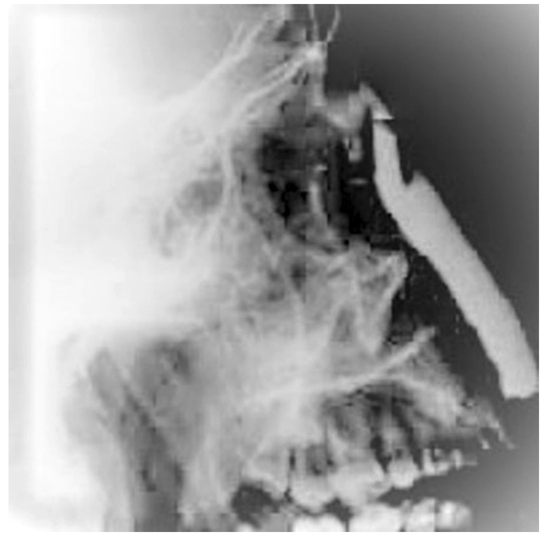

Fig. 8 True lateral skull radiograph showing 5–6 cm large shell fragment settled along mid of external nasal cavity, inflicting injury from frontal sinus to upper lip sulcus

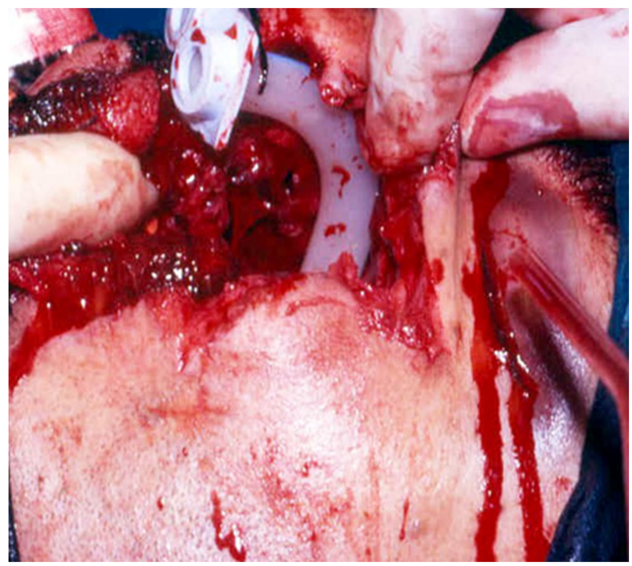

Fig. 9 Showing modified tracheostomy tube inserted through the nasal wound as a stent to scaffold intranasal fragmented tissues and nasal arch

Discussion

A good understanding of the complexity of the biophysics and pathophysiological interaction of blast, shrapnel and rifle bullet effects and management will help immediate providers and clinicians to decrease the mortality and morbidity of injuries.

Surgical reconstruction should start by the insertion of MCT as a central focal point for the NOE complex as an integral part of the process that requires concentration and attention. *Intercanthal* tissue can be stabilized using two

Fig. 10 Retrieved 5–6-cm-long large shrapnel, MCT anchored in proper position, 2 external plastic plates (buttons) on intercanthal space and 2 adapted portex tubes No. 8 for intranasal stability. Patient did excellent recovery

Fig. 11 Showing excellent results 2 months post operatively

buttons to contain *the intercanthal space and then fixed by nylon or silk sutures* that passed through the region.

Then intranasal stent procedure utilized has provided intranasal scaffolding and healing for fragmented tissues and achieved an esthetic surgical outcome. The technique is tolerated by the patient for more than one month and prevents nasal pyramid collapse and complete stenosis or block of the nasal cavity [16].

More aggressive techniques utilized by different researchers but faced with the comlexity of the midface blast/ballistics injuries. Undertacking primery

Fig. 12 Complications of war nasal injuries shows total nasal obstruction, results when no intranasal stenting and scaffolding of lacertid tissue was used

reconstruction by using for bone fragments fixing plates and screws is generally ill-advised and time-consuming for modren battlefield wounds [17]. It dramatically deprives the segments of the remaining blood supply, resulting in a subsequent loss of soft tissue. This causes the mucosa to shed from the bone fragments and causes the tissue wound to break down, becoming infected. There is no room to deglove the coronal/midface or administer the open-sky surgical exposure technique, which would provide the greatest potential surface disclosure to the upper and middle facial regions for usual trauma [18, 19].

External fixation has been utilized for unstable "flail" civilian nasal bones fractured and severely displaced nasal tissue. In this case, transmucosal, endonasal Kirschner wires are used for dorsal support until sufficient healing occurs [20].

Immediate reconstruction of the medial orbital walls and nasal dorsal bone grafts and allograft materials is not recommended for immediate war wounds because there are many factors that limit its application.

I have encountered cases in which the medial canthi have drifted laterally. I believe that this problem of canthal migration over time is difficult to prevent because the healing of thin fragmentary bone plates is usually through fibrous union, no matter the technique used.

Conclusion

The technique has been applied successfully for many years as an immediate and minimally invasive surgery which minimized the risk of tissue morbidity associated with the traditional approach. This uncomplicated and confirmed technique minimizes the chance of infection, preserves lacerated tissue, and maintains the remaining bony scaffold in its proper position until it heals.

Acknowledgments The author thanks Miss Gillian Elder and staff at the West Bloomfield Library in Michigan for their assistance in this paper.

Funding No any financial interests the authors may have in companies or other entities that have an interest in the information in the Contribution (e.9., National Institutes of Health (NIH); Welcome Trust; Howard Hughes Medical Institute (HHMI); grants, advisory boards, employment, consultancies, contracts, honoraria, royalties, expert testimony, partnerships, or stock ownership in medically related fields).

Compliance with Ethical Standards

Conflict of interest The author declares that there is no conflict of interest.

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